

Boiling

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• Last Class - I left off with transferring the Sweet Wort to the Kettle

Kettle - Boiling of the Wort

Purposes

- Sterilization of Wort
- Addition of Hops & other Finings
 - Hops → lower pH
 - Bitterness to counter balance Sweetness
 - Additional anti-microbial properties (IPA Origins)
- Protein Coagulation - Fittings
 - Beer stability and clarity
- Precipitation of Calcium phosphate
 - lowers pH
- Stripping
 - Dimethyl Sulfide (DMS)
 - $\left[\text{H}_3\text{C} - \text{S} - \text{CH}_3 \right]$ - BP 37°C
 - Undesirable Volatiles
 - Flavor and Color Development
 - Caramelization reactions → Nutty & Toffee
 - Melanoidins and Oxidation of Tannins → Darken Beer (good/Bad)
- Wort Concentration - $C_1V_1 = C_2V_2$

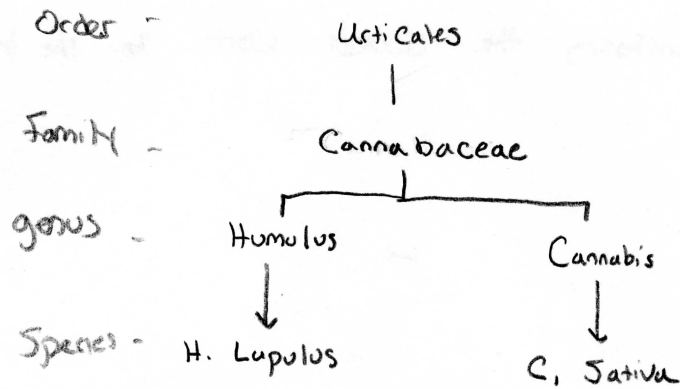
Dead Horse Arum Lily
- Attracts Flies

Boiling times are generally 60-120 minutes long

- Some systems can boil in 45 - specialized.

When moving Wort to/From Kettle avoid hot side aeration → Oxidation

HOPS



Added: to impart bitterness to balance Sweetness → iso-alpha acids
to impart Flavor/Aroma → essential oils
to increase head Stability

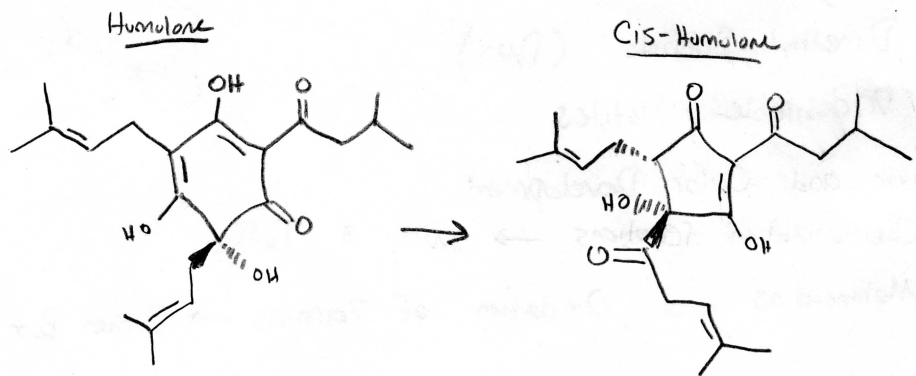
The longer hops are boiled for the more alpha acids are isomerized c.s.
trans
But: greater amounts of volatile essential oils are stripped

Bittering

Alpha acids come from the soft Resins in hops → Represent 2-16% total wt

3 Types of Acids

Humulone
Cohumulone
Adhumulone



X Look up other 2.

Utilization - the % of the alpha acids that get isomerized (go into wort)

- increases w/ longer boiling times, higher temps, boiling vigor, Pellet vs Whole
- decreases w/ higher gravity and opposite of above

Behave

Unfortunately, utilization does not ^{Behave} predictability that can be captured in an equation

- measured using laboratory Analysis such as ZIPLC.
- Instead Refer to tables

Hop Utilization values can range from 0 - 40% (roughly)

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- Tables will be posted online
- Are available from Hop growers
- equipment dependence → estimation

Bitterness - IBU (International Bittering Units) → $\left[\frac{\text{mg } \alpha\text{-Acids}}{\text{Liter of Beer}} \right]$

metric : Predicted IBU = $\frac{(\text{mg Hops})(\text{util } \%)(\text{Alpha Acid } \%)}{(\text{Liters})}$

↓ 28,350 mg/oz
3.785 Lit/gal

English : Predicted IBU = $\frac{(\text{oz Hops})(\text{util } \%)(\text{Alpha Acid } \%)(7,490)}{(\text{gallons})}$

→ Rearrange equations to know oz/mg of hops to hit target IBU

Example

12 Barrels Sweet Wort

SG - 1.043

90 minute Boil w/ evap rate 0.90 BBL/hr

10.65 BBL will remain ($P_{100^\circ\text{C}} = 8.000 \frac{\text{lbs}}{\text{gal}}$)

↓

10.22 BBL when cooled ($P_{15.5^\circ\text{C}} = 8.337 \frac{\text{lbs}}{\text{gal}}$)

SG - 1.0485

Hops Used: (Pellet Form)

util %

~10% - Saaz - 3.5% - 32 oz @ 10 min

~28% - Cascade - 8% - X oz @ 60 min

Target IBU - 28

IBU contributed by Saaz:

$$\frac{(10\% \text{ util})(3.5\% \alpha)(32 \text{ oz})(7,490)}{\left(\frac{10.22 \text{ BBL}}{51} \frac{\text{BBL}}{\text{gal}}\right)} = \frac{839}{317} = 2.6 \rightarrow 28 - 2.6 = 25.4$$

$$\frac{(317 \text{ gal})(25.4 \text{ IBU})}{(28\% \text{ util})(8\% \alpha)(7,490)} = \boxed{47.99 \text{ oz}}$$

Hops: Flavor and Aroma

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Bittering → Soft Resins ~ 2-16 % Hop wt

Aroma/Flavoring → Volatile Essential oils ~ 0.5 - 3.0 % Hop wt

- over 250 chemical compounds appear to contribute to aroma/flavor

3 Major Classes of Hop essential oils

Hydrocarbons ————— 80% of oil content

Oxygenated Hydrocarbons

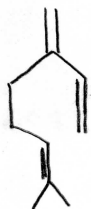
Sulphur-Containing Hydrocarbons ————— 20% of oil content

Other (ex: Glycosides Preboil Hopping)

Hydrocarbons - (Terpenes and Sesquiterpenes)

Myrcene - Aliphatic Compound - Monoterpene

→ Aliphatic - Non-aromatic compounds



Pungent

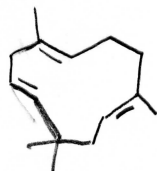
20 - 65% total oil

low in "noble" hops → Saaz, Tettnanger other "Flavor hops"

↳ can lead to oxygenated hydrocarbons:

linalool, geraniol, nerol and citral

Humulene - Cyclic - Sesquiterpene



Elegant

5-45% total oil

higher than myrcene in "Noble Hops"

↳ leads to:

Humulene epoxides (I, II, III)

Humulol

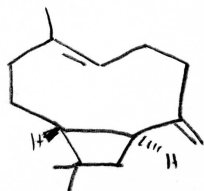
Humulene diepoxides (A, B, C)

Caryophyllene and Farnesene

5-15%

1-20%

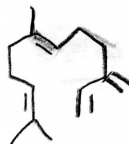
β -Caryophyllene



Caryophyllene epoxides

Caryolan-1-ol

β -Farnesene



Unknown Flavonin

Acts as a marker for identification of hop

High - aroma characteristics

low - Bittering "

Sulphur Containing

Hydrocarbons reacting w/ sulfur

episulfoxides, thioesters, polysulfides

Shunk Flavor

Flavor threshold 0.3 PPB

Other

Delta and Gamma - Cadinene

Alpha - muurolene

Beta - selinene

4 Characteristic Flavors/Aromas

- Spicy
- Herbal/Europcan
- Floral
- Citrus/Piney

<u>Aroma/Flavor</u>	<u>Compound From</u>	<u>Originates From</u>
<u>Spicy</u>	Humulene epoxides " " "diepoxides	Humulene oxidation
<u>Herbal</u>	Humulol linalool oxides Caryolan-1-ol	Humulene oxidation linalool Caryophyllene
<u>Floral</u>	linalool Geraniol Geranyl acetate Geranyl isobutyrate	Myrcene oxidation
<u>Citrus/Piney</u>	Citral Nerol limonene Cadinenes Beta-Selinene Alpha-Muurolene	Myrcene oxidation other
<u>Herbal/Spicy</u> <u>Hybrid</u>	Caryophyllene epoxide	Caryophyllene

Aroma Hops have:

α acid content - $< 6\%$.

myrcene oil - $< 50\%$.

oil content - $0.5 - 1.5\%$.

* Noble:

Humulene: Caryophyllene Ratio ($> 3:1$)

long term conditions

⑥ room temp for two months

Floral - (-) 11-12 %.

Herbal

Spicy - (-) 66-84 %.

Peacock

Fate of 11 top oil components in Bear